Vol. 41, No. 1 January 2012

PHYSICS & SOCIETY

A Publication of The Forum on Physics and Society • A Forum of The American Physical Society

Editor's Comments

I have the pleasure of opening this edition by welcoming aboard Maury Goodman of Argonne National Laboratory as the newest member of *P&S*'s editorial board. Maury's biographical details are summarized briefly under the News of the Forum below. The vitality of the Forum depends on the willingness of its members to contribute time and energy to Forum activities, and I am grateful to Maury for his willingness to serve in this capacity. Maury is replacing Ruth Howes, who is rotating off the board following a three-year term. Ruth's sound judgment, patience, and sense of humor were a tremendous asset in helping me get oriented when I became Editor; on behalf of the other members of the board, I thank her for her service, and wish her all the best.

One of the high points of our annual January edition is that it gives us a chance to recognize the accomplishments of individuals who have received Forum awards and APS Fellowship though Forum auspices. The details appear in the New of the Forum; I encourage readers to extend their congratulations to Burton Award winner Arian Pregenzer, Szilard Lectureship winner Siegfried Hecker, and new Fellows Jonathan Katz and William Rees; they will be formally recognized at the April meeting in Atlanta. Also, we are proud to note that *P&S*'s Assistant Editor, Jonathan Wurtele, is the recipient of the APS's 2011 John Dawson Award for Excellence in Plasma Physics Research for work involving the trapping of antihydrogen.

The Forum will again be sponsoring a number of sessions at the upcoming March and April national APS meetings in Boston and Atlanta, and our News of the Forum contains a summary of the very interesting talks scheduled for these sessions.

Our first feature article for this edition, by Jay Davis, examines technical and policy issues relevant to nuclear weapons numbers downsizing. This article is based on a talk Dr. Davis gave at the forum-sponsored session "Nuclear Weapons at 65" which was held at the APS April 2011 meeting in Anaheim. Our second feature article discusses the physics of a very different downsizing issue, but one that is much more personal for most of us, particularly at this time of year: the Body-Mass Index. Our book reviews look at a volume on nuclear energy prepared by Forum Past-Chair Charles Ferguson, and a treatment of the issue of communicating climate change to a public audience. Enjoy.

— Cameron Reed

IN THIS ISSUE

FORUM NEWS

Maury Goodman joins P&S Editorial Board

We are pleased to welcome Maury Goodman to the Editorial Board of P&S. Maury is replacing Ruth Howes, who is rotating off the Board after a three-year term. Maury is the leader of the neutrino group in the High Energy Physics Division at Argonne National Laboratory. He received his B.S. from M.I.T. in 1972, and his Ph.D. in physics from the University of Illinois in 1979, with a minor in Nuclear Engineering. He served as a postdoc at MIT until 1984, when he joined ANL. He has worked as a particle physicist, specializing in neutrinos and underground physics. He is currently on the MINOS, NOvA and Double Chooz neutrino experiments and recently became deputy spokesperson for LBNE, a new project for a long-baseline neutrino oscillation experiment using a beam at Fermilab and a detector at the Deep Underground Science and Engineering Lab (DUSEL) proposed for South Dakota. He has served on the APS investments committee, and was on the nominating committee of the FPS from 2001-2007 with 3 years as chairman. He was elected a fellow in the APS in 2008.

2012 Forum Award Recipients Announced

Recipients of the Forum's Joseph A. Burton and Leo Szilard Lectureship Awards for 2012 have been announced. The Burton Award is given to recognize outstanding contributions to the public understanding or resolution of issues involving the interface of physics and society. The recipient for 2012 is Arian Pregenzer of Stanford University "For her intellectual and managerial leadership in creating centers that allow international technical and policy experts to explore confidence building measures and other arms control regimes." The Leo Szilard Lectureship Award is given to recognize outstanding accomplishments by physicists in promoting the use of physics for the benefit of society in such areas as the environment, arms control, and science policy. The 2012 recipient of this award is Siegfried Hecker, also of Stanford University "For his leadership in developing international science and technology cooperation in areas critical to global security resulting in real reductions in the dangers of nuclear proliferation and nuclear terrorism." P&S extends congratulations to Drs. Pregenzer and Hecker on their well-deserved recognitions, and thanks the members of the selection committee for their work: Charles Ferguson (Chair), Granger Morgan, James L. Bonomo, and John Ahearne.

The deadline for nominations for the 2013 Burton and Szilard Awards is July 1, 2012. Information on Forum prizes and awards can be found at http://www.aps.org/units/fps/awards/index.cfm.

Assistant Editor Wurtele Receives Plasma Physics Research Award

Physics & Society is very pleased to note that Assistant Editor Jonathan Wurtele is the recipient of the APS's 2011 John Dawson Award for Excellence in Plasma Physics Research "For the introduction and use of innovative plasma techniques which produced the first demonstration of the trapping of antihydrogen."

New Fellows Elected through the Forum

Forum members Jonathan Katz and William Rees were elected to Fellowship at the November APS Council meeting through FPS nomination. Katz (Washington University) was recognized "For his significant and wide-ranging physics analyses at the interface of science and society, including nuclear weapons policy and the killing of oil well blow-outs". Rees is being recognized "For applying technical expertise and policy knowledge to strengthen the nation's physics enterprise." Rees joined the Bush Administration immediately after 9/11 to support the stand-up of the Science and Technology Directorate within the newly formed Department of Homeland Security. Later he joined the Department of Defense as the Deputy Under Secretary of Defense for Laboratories and Basic Science, where he oversaw $1.8 billion of annual funding in basic research. Katz, Rees, and the recipients of the Burton and Szilard awards will be recognized at the Forum Awards session at the April meeting in Atlanta (see below).

APS Congressional Science Fellowships

Applications for APS Congressional Science Fellowships are due January 13, 2012. Details can be found at http://aps.org/policy/fellowships/congressional.cfm. Congressional Fellowships are an opportunity for physicists who want to apply their knowledge and skills beyond the lab bench to the conduct of national policy. Fellows serve a one-year term working in the office of a Member of Congress or for a congressional committee. The fellowship term is for one year, usually running September through August. Benefits include a stipend of $70,000 per year, a relocation allowance, an allowance for in-service travel for professional development and reimbursement for health insurance up to a specified maximum.

FPS to Host Sessions at APS March Meeting

The annual March meeting of the APS will be held at the Boston Convention Center from February 27 – March 2, 2012. FPS is hosting three sessions; tentative titles of presentations are given here. Not all details of Forum-sponsored sessions were available at press time.

Monday, February 27, 2012, 8:00 AM

Broader Impacts of Research - NSF Policy and Individual Responsibility

Session Chair: Donald Prosnitz (Independent Consultant)

Science, the Scientists and Values, Alan I. Leshner (Chief Executive Officer, American Association for the Advancement of Science)

The APS and the Impact on Physics and Society, Barry C. Barish (California Institute of Technology)

Why Physicists have a Responsibility to Society, Charles D. Ferguson (Federation of American Scientists)

The Broader Impact Criteria - What's the solution? Don Prosnitz (Independent Consultant)

Tuesday, February 28, 2012, 8:00 AM

Novel and Proven Methods of Communicating Science to the Public

Session Chair: Brian Schwartz (Brooklyn College and The Graduate Center, CUNY)

Developing a Community-Based Theatre Company Committed to Science Plays, Debra Wise (Artistic Director, Underground Railway Theater and Catalyst, MIT)

Using Cartoons to Communicate Science, Todd Rosenberg (Odd Todd Studios)

Animating Conversational Portraits on Science and Scientists, Flash Rosenberg (Flash Rosenberg Studio)

The New Wave of Science Festivals and their Establishment, John Durant (Director, MIT Museum and the Cambridge Science Festival)

Celebrating 20 Years of Public Outreach of Science and Engineering in Portland. OR, Terry Bristol (President, Institute for Science, Engineering and Public Policy)

Thursday, March 1, 2012, 11:15 AM

Nuclear Power, One Year After Fukushima

Session Chair: David Wright (Union of Concerned Scientists)

A Technical Description of What Happened at Fukushima, Implications for Nuclear Power in Japan, and Lessons for the Future, Akira Omoto (Commissioner, Atomic Energy Commission, Japan)

Lessons from Fukushima for Improving the Safety of Nuclear Reactors, Ed Lyman (Union of Concerned Scientists)

Nuclear Power in China, Yun Zhou (Belfer Center for Science and International Affairs, Harvard University)

Nuclear Power in India, M. V. Ramana (Program on Science and Global Security, Princeton University)

FPS to Host Sessions at APS April Meeting

The annual April meeting of the APS will be held jointly with the annual Sherwood Fusion Theory Conference at the Hyatt Regency Atlanta Hotel in Atlanta, GA, from March 31 – April 3, 2012. The theme of the meeting is 100 Years of Cosmic Ray Physics. FPS is sponsoring five sessions. Not all details of times, locations, and speakers were available at press time.

Saturday, March 31, 2012, 10:45 am

FPS Awards Session

Session Chair: Pete Zimmerman (King's College, London)

Introduction of new Fellows elected through the Forum, presentation of Burton and Szilard Award recipients, and invited talks by them.

Saturday, March 31, 2012, 3:30 pm

The Forum at Forty

Session Chair: Puspha Bhat (Fermilab)

Keynote Speaker: Prof. Martin Perl (SLAC, Nobel Laureate, and one of the founding chairs of FPS) *Creativity and Funding Reality in Physics*.

Other Panelists/Speakers: Brian Schwartz, Pete Zimmerman, Dave Hafemeister, Andrew Zwicker

Monday, April 2, 2012, 10:45 am

New Developments in Radiation Detection Technologies & Nuclear Security

Session Chair: Doug Wright (LLNL)

Latest developments in radiation detection technology and nuclear security issues are discussed.

Nuclear Detection Architecture to Counter Nuclear Terrorism, Warren Stern (Director, Domestic Nuclear Detection Office, DHS)

TBD, Mike Kuliasha, (Director of Defense Threat Reduction Agency Nuclear Technologies, DOD)

Don't Mess with NEST (Nuclear Emergency Response Team), Mike Larson (LANL)

Monday, April 2, 2012, 3:30 pm

American Science & America's Future (Panel)

Session Chair: Pushpa Bhat (Fermilab); Moderator: Lawrence Krauss (Director, Origins Institute, Arizona State University)

How is the US going to maintain its leadership and competitive edge in the 21st century science and innovation? This panel session will address issues for scientific research, science education, S&T policies, scientific & technical workforce development, and impacts on industry and economy in the US in the new era. It is hoped that the discussion will also explore what measures might be necessary for the US to retain its strong leadership position in promoting and sponsoring science and technological development in the new global economy.

Keynote address: Dr. Shirley Ann Jackson (President, Rensselaer Polytechnic Institute; Member, President's Council of Advisors on Science and Technology).

Panel:

Dr. Neal Lane (Rice University, Former Presidential Science Advisor)

Rep. Dr. Rush Holt (To be confirmed)

Dr. Bill Foster (To be confirmed)

Dr. Jim Siegrist, Associate Director, High Energy Physics Division, DOE (To be confirmed)

Dr. Tim Hallman, Associate Director, Nuclear Physics Division, DOE (To be confirmed)

Tuesday, April 3, 2012, 10:45 am

Nuclear Energy, Safety & Security, Post-Fukushima

Session Chair: Charles Ferguson (Federation of American Scientists)

TBD, Richard Meserve (President, The Carnegie Institute of Science)

TBD, Mark Peters (Deputy Director for Programs, Argonne National Laboratory)

TBD, Harold Feiveson (Princeton University)

LETTERS

I enjoyed Danny Krebs' article "Personal Transportation in the 21st Century and Beyond" in the October issue of Physics and Society, as a nice review of the status of various alternative fuels for cars and trucks for the next decade or two. However, I was a little disappointed that the article didn't fulfill the promise of the title and outline some of the potential longer-term changes in personal transportation that could make a much more significant difference to the problem.

For example, many people now find much less thrill in driving themselves around than did those of earlier generations; to many it's a waste of time they could spend with their electronic gadgets. This has had a number of effects, particularly on transit ridership – see for example this study from just this year: http://www.apta.com/resources/statistics/Documents/Ridership/2011-q2-ridership-APTA.pdf that showed huge jumps in some cities (like Austin) that have been adding transit services, and generally a steady increase across the US. Can we expect "personal transportation" to decline in favor of public transportation in the 21st century? That would likely require both service increases and land-use changes (suburbs becoming more urban or at least town-centered) over the long term. It would have been nice to see some thoughts on the impact of such changes in Krebs' piece.

Then there are the self-driving cars, which Google has been experimenting with among others:http://www.nytimes.com/2010/10/10/science/10google.html. If people no longer care to drive themselves, which seems increasingly likely for the decades beyond 2020, that opens up a number of opportunities in improving the efficiency of "personal vehicles", which can then merge into spontaneous groups (cars can be much closer if human reaction times are eliminated) with efficiency approaching that of high-ridership buses or trains.

Electric vehicles also open up another opportunity - to move the fuel off the vehicle altogether. Electric trains pull their power from the tracks they pass over; at least one group in Japan has been experimenting with powering personal vehicles directly from the road in a similar fashion:http://www.smartplanet.com/blog/transportation/electric-roadways-would-allow-plug-in-cars-to-charge-on-the-go/963. The convenience and simplicity of this approach seem highly advantageous - but capital costing and payment mechanisms may make it hard to implement.

I hope *Physics and Society* will encourage more unconventional ideas of this sort in future articles on transportation solutions.

Arthur Smith (APS Life Member) , Selden, NY
arthurpsmith@gmail.com

Danny Krebs responds:

I agree with your comments. I was probably guilty of not thinking "out of the box" in the sense that I did not consider the possibility of attracting substantially more ridership to public transportation, or the potential for changing the nature of the highway system itself. My interest in this area grew out of a desire to look at the private automobile from a physics perspective along the lines of questions such as: How much horsepower does it take to cruise at highway speeds? [about 20 HP, assuming 70 mph, 30 mpg, and a 20% efficient engine]. How much peak horsepower is required to accelerate a 3000 pound vehicle zero to 60 in 10 seconds? [about 132 HP]. What is gasoline, anyway? [mostly aromatic hydrocarbons]. How real are biofuel solutions? [not very, at this point]. Could methane hydrate deposits be exploited? [probably not]. I had to modify the paper quite a bit when I presented it to the local Torch Club.

In my defense, evolutionary changes are generally cheaper and more readily implemented than revolutionary ones. I am not sure if petroleum dependence is a 50 year problem or a 5 year problem, but I am pretty sure that we better start working on solutions.

Danny J. Krebs
djkrebs@svsu.edu

ARTICLES

Technical and Policy Issues for Nuclear Weapons Reductions

Jay Davis

[Dr. Jay Davis, a nuclear physicist trained at the Universities of Texas and Wisconsin, is currently President of the Hertz Foundation, which funds graduate studies in the applied physical sciences and engineering. During a three-decade career at the Lawrence Livermore National Laboratory, Davis built accelerators for research in nuclear physics and for materials science in support of the fusion program. He left LLNL in 1998 for the Department of Defense, where, among other responsibilities, he served as founding Director of the Defense Threat Reduction Agency. This article is based on a talk Dr. Davis gave at a forum-sponsored session, "Nuclear Weapons at 65", held at the APS April meeting in Anaheim, April 30 – May 2, 2011. A summary of Davis's talk at the Anaheim meeting can be found in our July, 2011 edition – Ed.]

Introduction and Motivation

The past three years have seen renewed momentum in the area of nuclear arms control and in the reduction of the number of Russian and US weapons. The concept proposed in the Wall Street Journal in 2007 by the "Gang of Four" - William Perry, Henry Kissinger, Sam Nunn, and George Schultz - that it was possible to achieve a world without nuclear weapons changed the climate for arms control [1]. Their opinion piece was soon followed by the Obama Administration's embrace of arms control and the cancellation of President George W. Bush's Anitballistic Missile (ABM) concept in Europe, a move which brought the Russians back to the negotiating table. These developments led in turn to the successful negotiation and ratification of the New START Treaty, which sets limits on operationally-deployed strategic warheads and the number of strategic launchers [2]. New START preserves and increases the gains of the previous twenty years. The subsequent review conference for the Non Proliferation Treaty has added pressure for further steps in US and Russian reductions in accordance with Article Six of the 1968 Nuclear Non-Proliferation Treaty, which seeks eventual nuclear disarmament. Continuing concerns about proliferation risks in North Korea, Iran and the spread of technologies from Pakistan add to this pressure.

Why should we reduce the number of weapons? Reductions in numbers minimize risks for accidents or loss of control in weapons use. They also reassure non-weapons states and proponents of zero weapons that genuine progress is being made toward nuclear disarmament, and, if convincingly verified, build valuable trust and operational understanding between states. It is certainly true that Russia and the US have benefitted greatly from their shared experience over the past decades. At the same time, as the numbers go down, in some measure the value of each weapon rises and the consequences of cheating become greater. Beyond New START, or certainly the treaty that will follow it, the number of states involved in negotiations and inspections will increase, adding complexity to both negotiations and verification operations. At the same time, the cost and intrusiveness of inspection regimes will inevitably rise. As one young associate of mine has said, "There will be no Peace Dividend. There will be a Peace Surcharge."

The intent of this paper is to outline the issues that need to be addressed in the pursuit of steady reductions in weapons stockpiles, to set the context for future negotiations, to identify the varying constituencies that will be engaged in or influence negotiations, and to identify the "tradespace" across technology, operations and policy or doctrine. "Tradespace" is a term borrowed from military planning, where one is taught to seek solutions to problems by considering technology, operations and policy as components that can be traded off against one another to find an optimal plan to execute. In seeking to reduce nuclear weapons, issues arise in all of these areas. Inevitably, there is leakage across the boundaries; this is not a list of independent attributes. My goal here is not to depress readers with a plethora of impossible problems, but to give a sense of the complexity and interrelated nature of the positions and beliefs involved.

Technology Issues

The largest issue to arise in any treaty following New START is the need to change from counting weapons by assigning attribution rules to weapons platforms (so many weapons per ground-launched missile type, submarine, or bomber) to actually counting and tracking the weapons themselves. Additionally, as non-strategic weapons are now to be included in negotiations (as required by the US Senate Record of Ratification of New START and the stated policy of the Obama Administration), one will need to locate and inventory nuclear weapons that are not mounted on delivery systems, may be in bunkers, or are on very small systems that appear to be identical to conventional ordnance. The degree of intrusiveness of such inspections, the need to declare and then validate inventories, the possibility of compromise of non-nuclear military information such as stealth, radar, optical and sonar technologies, and the opportunity cost of allowing inspectors in sensitive military or industrial areas make negotiating acceptable treaty protocols a daunting prospect.

In addition to deployed weapons in the hands of militaries subject to inspection are the ancillary issues of declaring and verifying reserve weapons stockpiles, weapons designated as inactive and slated for disassembly, stockpiles of weapons materials, production facilities, and design laboratories. Many of these verifications are proposed to be done with attributes measuring systems. These are "black boxes" containing sophisticated measuring instruments such as high-resolution gamma spectrometers and neutron-multiplicity counters, but which retain all sensitive information internally behind information barriers and just give Yes-No indications with red and green lights. How these systems are to be developed, validated and operated in the field – and by whom – remains to be determined.

In addition, there are two fuel cycle issues. First is the problem of dealing with the fuel cycle of naval reactors, all of which (except the French reactors) currently use highly enriched uranium, which would be subject to a fissile-materials cut-off treaty at some point. This problem can be expected to grow with global warming as the opening of the Arctic will almost surely lead to a growth of nuclear powered icebreaker fleets. Presently only the Russians operate such vessels, but US and Canadian fleets may well follow. Second, despite the Fukushima event, the nuclear energy industry is surely going to continue to grow. Finding a way to guard against leakage of information from this industry to proliferators while protecting legitimate proprietary information will be difficult. Understanding how to move information for action across the barrier between weapons inspections, inherently a military activity, and nuclear power inspections, inherently a civilian activity, will be an interesting and challenging task.

Operational Issues

Where, how, and with whom do we develop, test and verify inspection tools and protocols? What is the role of inspectors from non-weapons states, who may be included of necessity, but who pose different risks in terms of information loss or acquisition? If weapons inventories and locations are in fact successfully verified, have larger security risks of terrorist acts been created? Are the declaration and inspection protocols of the Conventional Forces in Europe, one of the greatest confidence-building treaties ever, a model for dealing with nuclear weapons? It is one thing to do hands-on inspections of tanks and artillery pieces by serial number, but perhaps quite another to attempt tail-number counting of nuclear weapons in their bunkers (individual weapons are referred to by tail numbers).

Another set of issues arises with supporting forces and capabilities. The number of nuclear weapons seems quite "granular", but the numbers of submarines, bombers and ground-launched missiles are much less so. It is conceptually easy to go from 1600 deployed weapons to 1200, but much less simple to go from 16 ballistic missile submarines to 12. How to replace these systems, how to retain the capability to build and renew them, and how to create and retain the career paths for the excellent men and women to whom we entrust these systems are not simple industrial and social management issues. Similarly, the infrastructure and human skills of the nuclear weapons labs and the supporting manufacturing complex need to be adjusted to the size and needs of the reduced stockpile. And this complex must have a known and confident ability to expand and reconstitute should the future world suddenly turn dangerous and nuclear weapons inventories need to be increased in response to real security needs. The future nuclear weapons complex will be responsible for guarding against both unexpected failures in our deployed weapons systems that would affect performance, safety and surety, and against unexpected technical surprise in possible new systems fielded by opponents.

Policy Issues

A major issue in approaching negotiations is to decide what is the value and utility of the weapons themselves [3]. That all treaties to date, and likely all to come, never actually address the yields of the weapons in question suggests that the overwhelming value of the weapons is symbolic. If the weapons appear to establish deterrence at any yield, that is sufficient. The question of the credibility of extended deterrence, the assurance to a non-nuclear state that it will be protected from nuclear blackmail or attack due to the shield provided by the weapons and doctrines of a nuclear ally, has been deemed central to minimizing proliferation by nuclear-capable states for decades. Maintaining this concept is particularly difficult given the varying attitudes of NATO members towards the forward deployment of US non-strategic weapons, as will be discussed below. As numbers come down, at some point does one count inventories by blocs of nations – and what are those blocs? Is there an optimal mix of strategic and non-strategic weapons, and is it different for different states depending on their threat assessments and doctrines? Could such a different mix be adequately verified, and what possibility is there for leakage from non-strategic to strategic? To solve the problem of tactical weapons in Europe, would it be possible to establish and verify a large nuclear-free zone, e.g., Europe from the French border to the Urals, at acceptable costs and risks? The degree of intrusion necessary for successful verification might simply be beyond what any state will tolerate.

Another difficulty is the linkage, whether admitted or not, between high-tech conventional weapons and nuclear weapons. Many states, Russia and China in particular, see no attractiveness in lowering nuclear arsenals and subsequently being left vulnerable to compulsion by large and technically superior US conventional forces. A primary concern to the Russians is the development and deployment of an anti-ballistic missile defense by the US that would erode their deterrent. In many cases, non-nuclear weapons now can produce "nuclear-like" effects in terms of decapitation, infrastructure destruction or interruption, or near-total lethality on the battlefield. The ability of US carrier groups to project force far beyond US borders concerns many nations. The effects of US combined arms operations carried out by highly trained professional volunteer forces in two Gulf Wars have been studied and learned, not happily, by the militaries of both Russia and China: they both understand and fear that they cannot duplicate them for economic and technical reasons. Similar concerns exist for states facing opponents with near-equivalent technologies but overwhelming numbers, for example, Israel and Pakistan. Nuclear weapons are always an attractive and economical response to asymmetries in conventional forces. Having relied on nuclear weapons to counter stronger conventional forces during the Cold War, the US now finds others desiring nuclear weapons to deter it for the same reasons: we tend not to want to contemplate any peer emerging.

Finally, there is a serious emotional question. As the number of weapons comes down, the pretense of the Cold War that there were viable war-fighting theories for these weapons, i.e. weapons targeted on weapons, is simply not credible. As Clark Murdock of the Center for Strategic and International Studies pointed out years ago, deterrence is in the end established by targeting cities and populations [4]. Counter-force becomes counter-value. If one has just a few weapons, and wants to avoid misunderstanding about their use, there may have to be a very public discussion of use doctrine. Ambiguity, a friend of deterrence in years past, may not be helpful in a future world. Also, but beyond the scope of this article, is the whole question of the different reasons for which states beyond the US and Russia have or do not have weapons. The international community will need to agree on how to deal with those states that choose to remain outside the arms control norms.

The Opinions of Publics

The United States is notably constrained by understandings with and obligations to its allies. The several hundred American gravity bombs deployed in Germany, Italy, Belgium, the Netherlands and Turkey are a promise to NATO states (and those at the periphery) that they will be protected against nuclear threat or blackmail. The UK and France are NATO members, but maintain their own (and differing) doctrines for their own weapons. Despite differing opinions (the Germans now argue for removal of all US weapons from Europe, the Turks for retention in several countries as part of burden sharing) NATO expects consultation and discussion about the fates of these weapons, and does not want unilateral action or initiatives, by the US particularly, as a surprise. Some of the new Central European members, and the Baltic States in particular, see these weapons as their guarantee of freedom from bullying by the Russians. Interestingly, Pacific States such as Japan, Taiwan and South Korea apparently perceive the continued European deployment of US weapons in Europe as setting a precedent for doing the same in Asia if required, a linkage that is not at first obvious.

At the same time, the Russians, having taken their tactical weapons home from Eastern Europe after the collapse of Communism, see the forward-deployed US weapons as the main obstacle to any further treaties, referring to this as an unacceptable asymmetry. Fearful of invasion, they maintain a wide variety of weapons types, many obsolete and possibly not functional, to deal with these apprehensions. They assert a centrality of nuclear weapons to their security just as we in the West are questioning the utility of these weapons.

Finally, there are three distinct constituencies in the US whose opinions and concerns matter. The DOE and the National Nuclear Security Administration and their supporters have to manage the reduction in size of the weapons complex to support a smaller stockpile while maintaining hedge capabilities against the future. The military has to create and support the platforms, facilities and personnel that make training, security and safety, and possible nuclear operations credible. Investments to do these things must be traded against many others required as the two Middle East Wars ramp down. At the end, the varying concerns of Members of the Senate about national security, obligations to allies, and high-tech jobs in their states must be accommodated or assuaged if any treaty is to be ratified. The texture of possible agreement and compromise across all these issues is complex to say the least.

Possibilities and Proposals

There are some who dislike the treaty-by-treaty approach to arms reductions, saying that each step is left hostage to the willingness of the other side to make reciprocal concessions, asserting rather that a grand initiative by one side (almost always assumed to be the US) will break the conceptual log jam. Having looked at these problems from the lab, from the field, and from Washington for over twenty years, and mindful of the many constraints imposed on US actions both domestically and by allies, I think a grand gesture is not likely to happen.

I do accept a US obligation to lead in these matters, as we do have and will continue to have a position of both nuclear and conventional strength. Accommodating the desires of the Allies and the Russians would seem possible with a compromise agreement that sets a verifiable limit on the overall number of deployed nuclear weapons, but with a different mix of strategic and non-strategic weapons as each side desires. Negotiating the verification protocols for that agreement will set the path for any agreements that follow.

Acknowledgements

The thoughts in this paper come from many interactions and sources. Particularly important have been discussions with members of the study group for the APS Panel on Public Affairs as we produced its 2010 report "Technical Steps to Support Nuclear Arsenal Downsizing [5]". The discussion of NATO and tactical nuclear weapons has benefited greatly from the Arms Control Association and British American Security Information Council Report entitled "Reducing the Tactical Nuclear Weapons in Europe: Perspectives and Proposals on the NATO Policy Debate [6]". This exceptional report includes the varying positions of the members of the Alliance in excellent detail and clarity. It is a "must read" on this subject.

Finally, I would like to acknowledge the continuing inspiration of Former Secretary of Defense William Perry. His energy and devotion to the cause of reducing the risks from weapons systems he himself helped create and field in his long career is remarkable. His continued efforts in this area are astonishing.

References

1. *G. P. Schultz, W. J. Perry, H. A. Kissinger, S. Nunn, "A World Free of Nuclear Weapons," The Wall Street Journal, January 4, 2007, p. A15.*
2. *P. Podvig, "New START Treaty and Beyond," Physics & Society 39(3), 12-15 (July 2010).*
3. *Three articles on this topic, all titled "What Are Nuclear Weapons For," have appeared in Physics & Society: M. May, 36(4), 3-6 (October 2007); J. S. Foster and K. B. Payne, 36(4), 7-10 (October 2007); I. Oelrich, 37(2), 10-13 (April 2008).*
4. *See, for example, "Exploring the Nuclear Posture Implications of Extended Deterrence and Assurance," by C. Murdock and J. M. Yeats; http://csis.org/publication/exploring-nuclear-posture-implications-extended-deterrence-and-assurance*
5. *The POPA report can be found at http://www.aps.org/policy/reports/popa-reports/upload/nucleardownsizing.PDF*
6. *The report can be found at http://www.basicint.org/sites/default/files/Tactical_Nuclear_Report_May_10.pdf*

Jay C. Davis
The Hertz Foundation
jcd@hertzfoundation.org

Physics of the Body Mass Index

S. P. Apell, O. Wahlsten and H. Gawlitza

The individual and societal costs of obesity are well known: excess cardiovascular stress, chronic and cancerous diseases, and early mortality [1]. For this reason, there is considerable medical and popular interest in having a simple, reliable, and cheap way to monitor health risks by reducing physiological features of obesity to a single number. Such a number could also facilitate comparisons of health status between different regions, populations, ages and genders, and it could help an individual monitor his or her own body. Perhaps the best-known such number is the *Body Mass Index* (BMI). In this article we develop a straightforward, physically-motivated model to cast the definition of the BMI into some interesting equivalent forms, and show that it has a fundamental physical justification in terms of bodily metabolic rate and heat loss.

A Brief History

The BMI is not the only index of general health and weight status. Several alternative and complementary indices such as the Ponderal Index, Body Volume Index, Skin Fold Method, Waist-to-Hip Ratio, and Sagittal Abdominal Diameter have been developed [1]. Through a comparative study of obesity indices, Ancel Keys of the University of Minnesota and his collaborators introduced in 1972 the notion of *body mass index* as the best performing such measurement [2]. This was a renaming of the *Quetelet index* proposed in 1832 by the Belgian mathematician, astronomer and statistician Adolphe Quetelet, who was also known as the "founder of social physics." Quetelet did not intend his index to be used to characterize obesity or general health status, but rather to help him define a "normal man" by fitting a Gaussian curve to the distribution he found for the index, since using mass alone did not work [3].

For a person of weight M (kilograms) and height H (meters), BMI is defined as [4, 5]:

$$\mathrm{BMI} = M/H^2 = \rho V/H^2,$$

where we assume that an individual has an average body density $\rho = (M/V)$ where V is the body volume. The Centers for Disease Control cautions that while the correlation between BMI and body fat is fairly strong, there are variations by race, sex, and age [6]. For adults, CDC guidelines classify a person with a BMI of ≤ 18.5 as underweight, 18.5 to 24.9 as normal weight, 25 to 29.9 as overweight, and ≥ 30 as obese. If M and H are measured in pounds and inches, then M/H^2 must be multiplied by a factor of 703 to give the BMI on this scale. For aspects of BMI related to children, see [7].

A Prolate Spheroidal Model Human

Quetelet constructed his index based on the empirical finding that the weight of adult humans scales with the square of their height. If we grew equally in all directions our weight would grow as the cube of our height, a model often used in many physics papers on animal scaling (see, e.g., [8]), but this is the case only during our first year of growth. A physicist's common first-approximation approach of modeling a system as a sphere is not applicable to human beings: if it were, our weight would increase by a factor of 27 in the time that we grew from a height of two feet to six feet! The next simple model one might think of, a right circular cylinder, would also not do as it would not capture the notion that most people are wider in their middles than at their ends. To represent adult proportions, we need a more realistic model intermediate between these two extremes. Also, since most people are very concerned with their waistline circumference W, it would be handy to cast the formulation of BMI in terms of that measurement.

Consider modeling a person as a prolate spheroid, that is, as an ellipse rotated about its major axis. With the person's height as the major axis and their waistline diameter D as the minor axis, their volume will be proportional to HD^2, or, in terms of their waistline circumference, $V \sim HW^2$. Hence, dropping unnecessary constants,

$$\mathrm{BMI} \sim \rho\, HW^2/H^2 \sim \rho W^2/H.$$

Average body density does not vary much among the population, even between very obese and very muscular people, so ρ can be treated as essentially constant [9]. Your height H will not vary much once you have reached adulthood, so you can conclude that your BMI depends on the square of your waistline measurement. Adding an inch to a 36-inch waist at a BMI of 22 will push your BMI to just over 23.

Another perspective is provided by eliminating height in favor of weight via $H \sim M/\rho W^2$, which gives

$$\mathrm{BMI} \sim \rho^2\, W^4/M.$$

For a group of people *of the same mass*, BMI varies as the fourth power of waistline, a result which strikingly emphasizes the role of an individual's waist/height "aspect ratio" in computing their BMI. As a side comment, it is interesting to note that resistance to laminar flow in arteries and veins also scales with the fourth power of their circumference; one is led to wonder what effect these fourth-power dependencies have on human evolution.

Energy Considerations

The most fundamental aspect of many physical systems is their energy budget. If we wish to construct an index which in some sense measures the accumulation of unnecessary fat reserves, we should compare energy input versus energy loss. For most animals, biologists measure the energy input via the so-called basal metabolic rate, which scales as about the three-fourths power of body mass, BMR ~ $M^{3/4}$. There are slight variations in the exponent when one starts to go into details of various animal groups as well as interpreting data for one single group, but our purpose here is to develop a simple physical argument [10,11]. As for energy loss, for an organism that is simply sitting around, we consider heat leaving the body as the major energy output. This will be proportional to its surface area S, hence

$$(\text{energy input/energy output}) \sim W^{3/4}/S.$$

Mosteller [12] found that body surface area scales as the square root of the product of a person's weight and height, a result supported by later findings [13, 14]. This gives

$$(\text{energy input/energy output}) \sim W^{3/4}/(WH)^{1/2} \sim W^{1/4}/H^{1/2} \sim (\text{BMI})^{1/4}.$$

Physically, Quetelet's empirical index introduced nearly 200 years ago can be interpreted as the ratio of the basal metabolic rate to the body's heat loss rate to the *fourth* power. Increasing your caloric intake without a corresponding increase in energy burn-off will thus have a serious effect on your BMI. The fourth-power dependence shows why it is difficult to improve a BMI once it has reached an unhealthy number. Since the possible amount of stored energy in the form of fat tissues should be related to the metabolic rate and the amount of lost energy is related to surface area, a large storage capacity coupled to a relatively small area will give a large index - the case for "spherical" individuals. The best advice for us humans is to strive for a relatively large eccentricity and watch out for changes in our waistline.

It is always instructive to examine the physical bases for everyday phenomena. Following in the tradition of Quetelet's social physics, we have explored here how a common measure of human health relates to basic geometrical and energy-balance quantities.

Finally, we want to point out that Quetelet's observations also imply that the metabolic rate is beautifully fine-tuned to be directly proportional to the body surface area. In contrast, a simplified physical "spherical cow" argument leads to the suggestion that there is a lower limit to the size of animals based on the false assumption that energy generation is proportional to volume and losses (true) to the area, and that eventually the latter wins for small enough an animal. In fact, as pointed out in [15], the lower limit is related to when cells begin behaving independently from each other rather being part of an individual (in vivo versus in vitro).

We encourage readers to consider how this and other socially-relevant measures might be similarly as well as further analyzed.

References

1. *R. Huxley, S. Mendis, E. Zheleznyakov, S. Reddy and J. Chan,* Body mass index, waist circumference and waist:hip ratio as predictors of cardiovascular risk – a review of the literature, *European Journal of Clinical Nutrition **64**(1), 16-22 (2010).*
2. *A. Keys, F. Fidanza, M.J. Karvonen, N. Kimura and H.L. Taylor,* Indices of Relative Weight and Obesity, *J. Chron. Dis. **25**(6-7), 329-343 (1972).*
3. *G. Eknoyan,* Adolphe Quetelet (1796-1874) – the average man and indices of obesity, Nephrology Dialysis Transplantation ***23**(1), 47-51 (2008).*
4. *A. Quetelet,* Recherches sur le poids de l'homme aux different ages. *Nouveaux Memoire de l'Academie Royale des Sciences et Belles-Lettres de Bruxelles. 1832, t. VII.*
5. *A. Quetelet,* A Treatise on Man and the Development of his Faculties. *Originally published in 1842. Reprinted in 1968 by Burt Franklin, New York.*
6. *http://www.cdc.gov/healthyweight/assessing/bmi/adult_bmi/index.html (Sept 14 – 2011)*
7. *N. J. MacKay,* Scaling of human body mass with height; the Body Mass Index revisited, *J. Biomech. **43**(4), 764-66 (2010).*
8. *H. Lin,* Fundamentals of biological scaling, *American Journal of Physics **50**(1), 72-81 (1982).*
9. *For an extreme being of only fat or only muscles there is a density change of less than 20%.*
10. *C.R. White and R.S. Seymour,* Mammalian basal metabolic rate is proportional to body mass$^{2/3}$, *PNAS **100**(7), 4046-49 (2003).*
11. *G.B. West, W.H. Woodruff and J. H. Brown,* Allometric scaling of metabolic rate from molecules and mitochondria to cells and mammals, *PNAS **99**(Supplement 1), 2473-78 (2002).*
12. *R.D. Mosteller,* Simplified calculation of body-surface area. *N Engl J Med **317**(17), 1098 (1987).*
13. *T.K. Lam and D.T. Leung,* More on simplified calculation of body-surface area. *N Engl J Med **318**(17), 1130 (1988).*
14. *B.J.R. Bailey and G.L. Briars,* Estimating the surface area of the human body, Statistics in medicine ***15**(13), 1325-32 (1996).*
15. *G. B. West, W.H. Woodruff, and J. H. Brown,* Allometric scaling of metabolic rate from molecules and mitochondria to cells and mammals, *PNAS **99**, 2473-2478 (2002).*

S. P. Apell, O. Wahlsten and H. Gawlitza
Dept of Applied Physics, Chalmers Univ of Technology , SE-412 96 Göteborg, Sweden
apell@chalmers.se

REVIEWS

Engaging the Public with Climate Change: Behaviour Change and Communication.

Edited by Lorraine Whitmarsh, Saffron O'Neill and Irene Lorenzoni. Earthscan. (2011). ISBN 978-1-84407-928-5. Distributed in the USA by Stylus Publishing.

Aux Armes! Was the cry of eminent climatologists as they considered the dire consequences of continuing global warming. But their impact on politicians and the general public has been notoriously slow and unproductive. This book emphasizes that reliance on technological explanation is a necessary but insufficient component for action by a mobilized society. It presents an analysis of how to engage a very diverse public through theoretical insights (Part 1: the first 7 chapters) and innovative practical initiatives (Part 2: chapters 8-14). Instead of Physical Science this book is concerned with Political and Social Science backed by Economic and Social Psychology, Communication, Marketing and Neuro-science.

As a physicist I found that reading a book more in touch with sociology quite a challenge. The amount of detail and the vast number of references (50-80 per chapter) make it difficult to assimilate and suggests that the book is more appropriate for the research specialist in the fields mentioned above, rather than for the more general reader.

It is a collection of articles written by 21 different writers, the majority (16) of whom are in United Kingdom institutions. Consequently, it is largely centered on the experience in the UK. However many of the ideas and projects are of universal application and people from other countries could benefit from their consideration. Below I give the chapter titles and notes on a selection of chapters to give the reader a taste of what this book covers.

PART 1:

Chapter 1. "Old Habits and New Routes to Sustainable Behaviour" studies the social psychology and sociological aspects of habit changing. Research indicates that people with strong habits are less interested in an information campaign than non-habitual individuals. With this in mind and considering the need for rapid change, the suggestion is that an effort should be made to change behavior first and attempt to apply motivational effort thereafter. One way to change behavior is through legislation. There is evidence that this led to more negative attitudes towards smoking.

Chapter 2. Carbon Budgets and Carbon Capability: Lessons from Personal Carbon Trading (PCT). It pursues the idea that issuing personal CO_2 emission rights to citizens might mitigate climate change at individual and societal levels. This is a feature of the UK Green Party's climate change policy. In the UK there are over 30 groups of CRAGS-Carbon Rationing Action Groups adopting some aspects of PCT, and the idea has spread to Canada and the US. This chapter highlights the lessons from economic and social psychology applicable to PCT.

Chapter 3. Public Engagement in Climate Action: Policy and Expectations. This chapter provides an analysis of how the responsibilities and engagement of the public have been represented within recent climate change and related documents in the UK, and how and why the public takes actions or not. The analysis reiterates that when asked to engage in mitigating climate change, people are likely to evaluate engagement against a set of environmental, social, economic and political criteria, rather than focusing on technological cuts in greenhouse gases which official guidelines currently exhort people to do. Climate change is a collective problem, requiring social debate about the structure of mitigating programs the public would appreciate.

Chapter 4. The Role of Social Comparisons in Promoting Public Engagement with Climate Change. Do negative comparisons with other groups and countries encourage us to improve our own performance? Would positive comparisons that highlight previous success work better? This chapter seeks to answer these questions and to explore conditions under which positive and negative comparisons translate into increased engagement with climate change and other sustainability issues.

Chapter 5. Dismantling the Consumption-Happiness Myth. This chapter argues that the Consumption-Happiness Myth locks us into specific patterns of consumption because of its impact on four key elements which are discussed in detail. It also analyses the role the pursuit of pleasure plays in motivating human behavior in terms of new technologies in neuroscience involving complex networks of neural pathways, and specifically in the part played by the amygdala. The findings provide useful insights for social marketers in commercial advertising and could be useful in the influence on climate change behaviors.

Chapter 6. Public Engagement with Climate Adaption: An Imperative for Institutional Reform?

Chapter 7. Ecological Engagement as Public Engagement with Climate Change.

PART 2. Methods, Media and Tools.

Chapter 8. Engaging People in Saving Energy on a Large Scale: Lessons from the Programmes of the Energy Saving Trust in the UK.

Chapter 9. Keeping Up with the Joneses. The Impacts and Limits of Social Learning in Eco-renovation. Recently in the UK, there have been an increasing number of community organized "Eco-Open Homes" where eco-renovated or eco-new built homes are open to the public. The greatest strength of these events is the power of real life experience and the telling of a 'Story' by ordinary citizens about their own homes combined with the visitor's experience of being in and seeing the homes. The opportunities and barriers of this approach are studied and the bottom-up approach of this example of social learning is examined.

Chapter 10. Up-scaling Social Behaviour Change Programmes: The Case of Eco-Teams.

Chapter 11. The Role and Effectiveness of Governmental and Non-governmental Communications in Engaging the Public with Climate Change.

Chapter 12. Communicating Energy Demand: Measurement, Display and the Language of Things. This paper argues that the transformation of our energy systems towards lower environmental impact require us to make usage and supply more visible, and the connections between them more obvious. This implies that the public should change their attitude from energy as commodity—something that can be packaged and measured—to energy-as-infrastructure. One way of doing this is to use smart metering involving two-way communications in which the recipient sees usage of component parts and can interact to modify them.

Chapter 13. The Role of New Media in Engaging the Public with Climate Change. This chapter reviews and critically evaluates the current role, and potential roles new media would play in engaging the public with climate change. New Media are (is??) integrated, interactive and using digital code. Opportunities and Limitations are studied for three overlapping key themes, information, interactivity and inclusivity. Major problems include the separation of falsehoods from the facts fractionization and new forms of localism (e.g., networks promoting local events) the freedom of entry accorded to both pro- and anti-mitigation points of view.

Chapter 14. Low Carbon Communities: A Grassroots Perspective on Public Engagement (i.e., what people know and do relative to mitigation and adaption to climate change). This chapter asks the questions why people find it hard to engage with global warming, what are the psychological and social mechanisms that will allow their engagement, release creativity, change behavior and move closer to a low carbon society. Community-led projects have learned that the best way to gather support and enthusiasm for their projects is to provide easy routes to participation. The methods of several groups are described in some detail.

Chapter 15. What Have We Learnt and Where Do we Go from Here?

We need to recognize the essential roles of disciplines besides those offered by the physical science. A great diversity of approaches to engaging the public with climate change is available. While there is a role for fear messaging, many chapters argue for the importance of positive motivational messaging. Civic and community engagement is important in shaping social change. Evaluation of engagement activities is a necessary key to fuller understanding of the success to otherwise of these activities.

To many brought up in the physical sciences, the emphasis on the non-physical may be something of an eye-opener with further consideration. Many of the projects start small and develop slowly, which is fine if we have plenty of time at our disposal. But one wonders if major operations applied quickly are needed to rescue Earth, our home!

Peter Schroeder
Emeritus Professor of Physics, Michigan State University
Schroeder26@gmail.com

Nuclear Energy: What Everyone Should Know

by Charles D. Ferguson, Oxford University Press, 2011, ISBN 978-0-19-975946-0, 222 pages, $16.95

This is a good reference for any reader who has a working knowledge of nuclear technology. The topic is divided into eight chapters, and each chapter is divided into sections in which posed questions are answered. As an example, Chapter 4, "Proliferation," is separated into sixteen topic questions, an example of which is "Has commercial nuclear power been used to produce nuclear weapons?" The book includes information about the recent nuclear power plant accident in Japan.

The first forty-one pages consist mostly of basic information about nuclear science and nuclear energy technology. For readers versed in these topics this section may be reviewed quickly. The remainder of the book addresses several important topics, including energy security, climate change, nuclear safety, radioactive waste management, and sustainable energy.

The book contains a great deal of factual information. Examples include: the cost of a new large reactor (9 billion dollars); the skilled professionals needed to build and start up one new nuclear plant (1,000 operations and maintenance staff, 200 quality control inspectors, 400 construction inspectors, 500 construction engineers, 100 Nuclear Regulatory Commission inspectors, and 300 people to start up the plant); the number of weapons in the inventories of the nuclear-armed states (nine nations are listed including the top three – U.S 5,113, Russia 4,600, France 350); proliferation-proofing the nuclear fuel cycle (the American Physical Society indicates there is no proliferation-proof nuclear technology); how safe are today's nuclear power plants (least safe are the eleven Chernobyl-type reactors in Russia); a comparison of the radioactivity emitted by nuclear plants versus coal-fired plants (the radiation risk from a coal-fired plant is very small – 1.9 millirems from ash per person per year, versus 360 millirems per U.S. person per year from general background radiation).

The last two chapters deal with the challenge of nuclear waste management, and sustainable energy. These are key problems that must be solved, and the author addresses potential solutions. Also included is an extensive bibliography.

The question / answer format of the book enables numerous issues to be analyzed and addressed. At the same time the format is somewhat dry. Readers with a general interest in nuclear energy may find themselves plodding through some of the topics, but it is obvious that Charles Fergusson did extensive research in preparing the book.

Frank Lock
Gainesville, GA
fasterlock@att.net

Physics and Society is the non-peer-reviewed quarterly newsletter of the Forum on Physics and Society, a division of the American Physical Society. It presents letters, commentary, book reviews and articles on the relations of physics and the physics community to government and society. It also carries news of the Forum and provides a medium for Forum members to exchange ideas. ***Opinions expressed are those of the authors alone and do not necessarily reflect the views of the APS or of the Forum.*** Contributed articles (up to 2500 words, technicalities are encouraged), letters (500 words), commentary (1000 words), reviews (1000 words) and brief news articles are welcome. Send them to the relevant editor by e-mail (preferred) or regular mail.

Physics and Society **can be found on the web at http://www.aps.org/units/fps.**